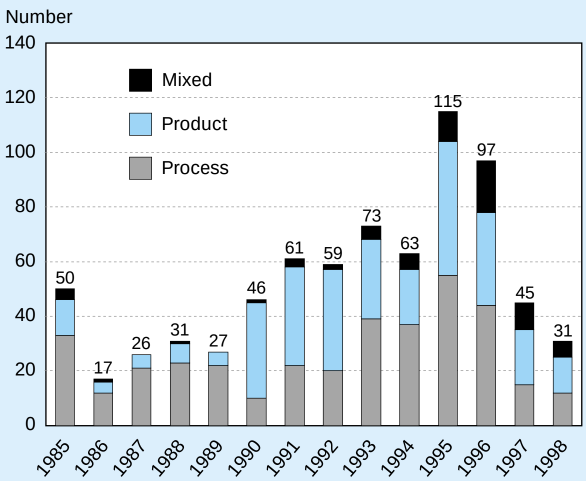
Figure 2-25.
Growth in R&D consortia registered under the National Cooperative Research and Production Act



SOURCE: Link (1999) and unpublished tabulations.

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Other observations include:

- The industry with the most RJVs over the 1985–98 period was communication services (standard industrial classification, or "SIC," number 48), which claimed 131 of the 741 total. The electronics industry (SIC 36) was a close second with 120, followed by transportation equipment (SIC 37) with 115.
- The average number of members per RJV over the 1985–98 period was 13; this number varied by industry, however, from an average of only 6 members for the communications services industry to an average of 25 for the electronics industry.
- Only 10 percent of all RJVs included Federal laboratories as research members. Among RJVs in the communications services industries, less than 1 percent had Federal labs as members. Among those in machinery and computer equipment (SIC 35), 21 percent included Federal labs; among those in electronics, 20 percent included Federal labs.
- Sixteen percent of all RJVs included universities as research members. For communications services, this percentage was as low as 5, whereas for electronics it was as high as 34.
- As many as 29 percent of all RJVs had foreign affiliates as research members, ranging from 17 percent for transportation equipment to 45 percent for the oil and gas extraction industry (SIC 13).
- Fourteen percent of RJVs had an environmental research focus; no RJVs in communications services had an environmental research focus, whereas 43 percent in chemicals and allied products (SIC 28) had that focus.
- Forty-nine percent of RJVs (365 of the 741 total) had research that was process-focused; 41 percent (307) had research that was product-focused; and the remaining 9 percent (69) had research that included both. (See figure 2-25.)

International Comparisons of National R&D Trends

Absolute levels of R&D expenditures are indicators of the breadth and scope of a nation's S&T activities and are a harbinger of future growth and productivity. Indeed, investments in the R&D enterprise strengthen the technological base on which economic prosperity increasingly depends worldwide. Findings from a study of 25 countries by Porter and Stern (1999) indicate that human talent and R&D spending are among the most important factors contributing to nations' innovative capacity. Consequently, the relative strength of a particular country's current and future economy—and the specific scientific and technological areas in which a country excels—is further revealed through comparison with other major R&D-performing countries. This section provides such comparisons of international R&D spending patterns.[36] It examines absolute and relative expenditure trends, contrasts performer and source structural patterns, reviews the foci of R&D activities, and looks at government priorities and policies. Although R&D performance patterns by sector are similar across countries, national sources of support differ considerably. In nearly all OECD countries, government has provided a declining share of all R&D funding during the past decade, whereas the industrial share of the funding total has increased considerably. Foreign sources of R&D have been increasing in many countries.

Absolute Levels of Total R&D Expenditures

The worldwide distribution of R&D performance is concentrated in relatively few industrialized nations. Of the $500 billion in estimated 1997 R&D expenditures for the 28 OECD[37] countries, 85 percent is expended in just 7 countries (OECD 1999d). These estimates are based on reported R&D investments (for defense and civilian projects) converted to U.S. dollars with purchasing power parity (PPP) exchange rates.[38] (See appendix table 2-2.)

[36]Most of the R&D data presented here are from reports to OECD, which is the most reliable source of such international comparisons. A fairly high degree of consistency characterizes the R&D data reported by OECD, with differences in reporting practices among countries affecting their R&D/GDP ratios by no more than an estimated 0.1 percentage point (ISPF 1993). Nonetheless, an increasing number of non-OECD countries and organizations now collect and publish internationally comparable R&D statistics, which are reported at various points in this chapter.

[37]Current OECD members are Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, South Korea, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom, and the United States.

[38]Although PPPs technically are not equivalent to R&D exchange rates, they better reflect differences in countries' laboratory costs than do market exchange rates. (See sidebar, "Purchasing Power Parities: Preferred Exchange Rates for Converting International R&D Data.")

Advanced Technology Program Funding Slows

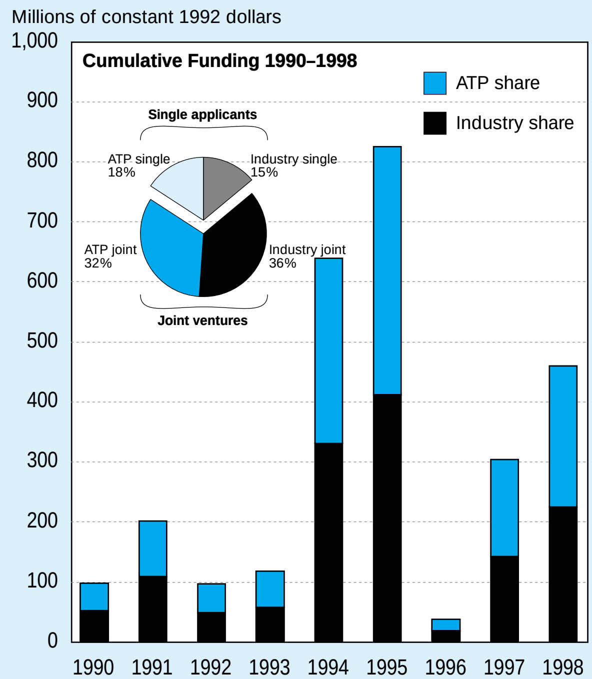
Two Federal technology partnership programs were started in the 1990s: DOC's Advanced Technology Program (ATP) and DOD's Technology Reinvestment Project (TRP). The purpose behind both programs was to spur the development and deployment of high-risk enabling technologies through an industry-driven, cost-sharing process whereby industry proposed the research and supplied at least half of the funding. Of the two programs, only ATP survives, and its budget was sharply reduced in 1996.

The cumulative shares of ATP funding from 1990 to 1998 by government and industry have been nearly the same: $1.3 billion in constant 1992 dollars. (See appendix table 2-61.) The 285 single-applicant projects have a cumulative total funding level of $851 million in constant 1992 dollars, with ATP funds accounting for 55 percent and industry funds accounting for 45 percent. The average award size across single applicants and joint ventures has been $6.1 million in constant 1992 dollars. The 146 joint ventures have had a cumulative funding level of $1.8 billion in constant 1992 dollars, of which 53 percent was provided by industry participants.

ATP runs two kinds of competitions—general and focused. Companies or consortia can submit proposals for support in any technology area(s) in the general competitions, whereas the focused competitions are for specific technologies. Proposals are selected through a peer review process and are judged on their technical merit and their potential for commercial success.

The ATP program was most active in 1994 and 1995. (See figure 2-26.) In fact, funding in these two years alone, in real terms, accounted for 53 percent of all funding over the 1990–98 period. In 1996, funding had nearly vanished to $34 million (in 1992 dollars), but it has picked up again in 1997 and 1998, with levels of $273 million and $408 million, respectively. In every year from 1990 to 1998, the ATP and industry shares have been close to 50 percent each.

Figure 2-26.
Advanced Technology Program funding



SOURCE: U.S. Department of Commerce, National Institute of Standards and Technology.

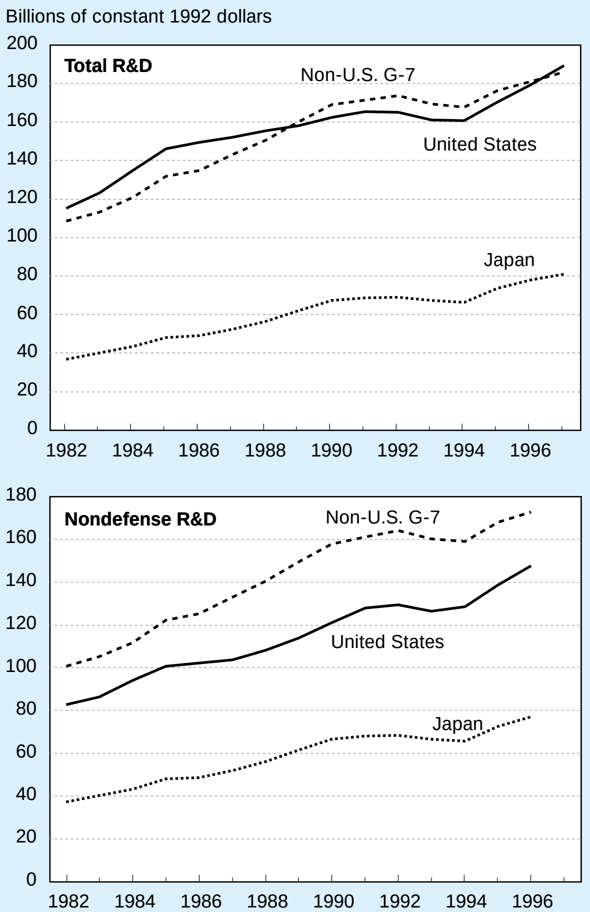
See appendix table 2-61. *Science & Engineering Indicators – 2000*

The United States accounts for roughly 43 percent of the OECD member countries' combined R&D investments; U.S. R&D investments continue to outdistance, by more than 2–to–1, R&D investments made in Japan, the second largest R&D-performing country. Not only did the United States spend more money on R&D activities in 1997 than any other country, it also spent as much by itself as the rest of the G-7 countries—Canada, France, Germany, Italy, Japan, and the United Kingdom—combined. (See appendix table 2-63.)[39] In only three other countries—the Netherlands, Australia, and Sweden—do R&D expenditures exceed 1 percent of the OECD R&D total (OECD 1999d).

In 1985, spending in G-7 countries other than the United States was equivalent to 90 percent of U.S. R&D expenditures that year. The non-U.S. total climbed steadily to peak at 105 percent of the U.S. total in 1993. Since then, however, non-U.S. G-7 R&D expenditures have slipped back to an amount equivalent to about 98 percent of the U.S. total. (See figure 2-27.) Initially, most of the United States' relative improvement vis-á-vis the other G-7 countries since 1993 resulted from a worldwide slowing in R&D performance that was more pronounced in other countries than in the United States. That is, although U.S. R&D spending stagnated or declined for several years in the early to mid-1990s, the reduction in real R&D spending in most of the other large R&D-performing countries was more striking. In Japan, Germany, and Italy, inflation-adjusted R&D spending fell for three consecutive years (1992, 1993, and 1994) at a rate of decline that exceeded similarly falling R&D spending in the United States. In fact, large and small industrialized countries worldwide

[39]International data availability has become less timely over the past several years, so 1997 is the most recent year for which R&D statistics are widely available from many countries. Part of the delay in obtaining current R&D statistics is a result of resource pressures affecting national statistical offices; part is a result of resource constraints facing international organizations that provide internationally comparable data.

Figure 2-27.
U.S. and other G-7 countries' R&D expenditures



NOTE: The non-U.S. G-7 countries are Canada, France, Germany, Italy, Japan, and the United Kingdom.

See appendix tables 2-63 and 2-64.

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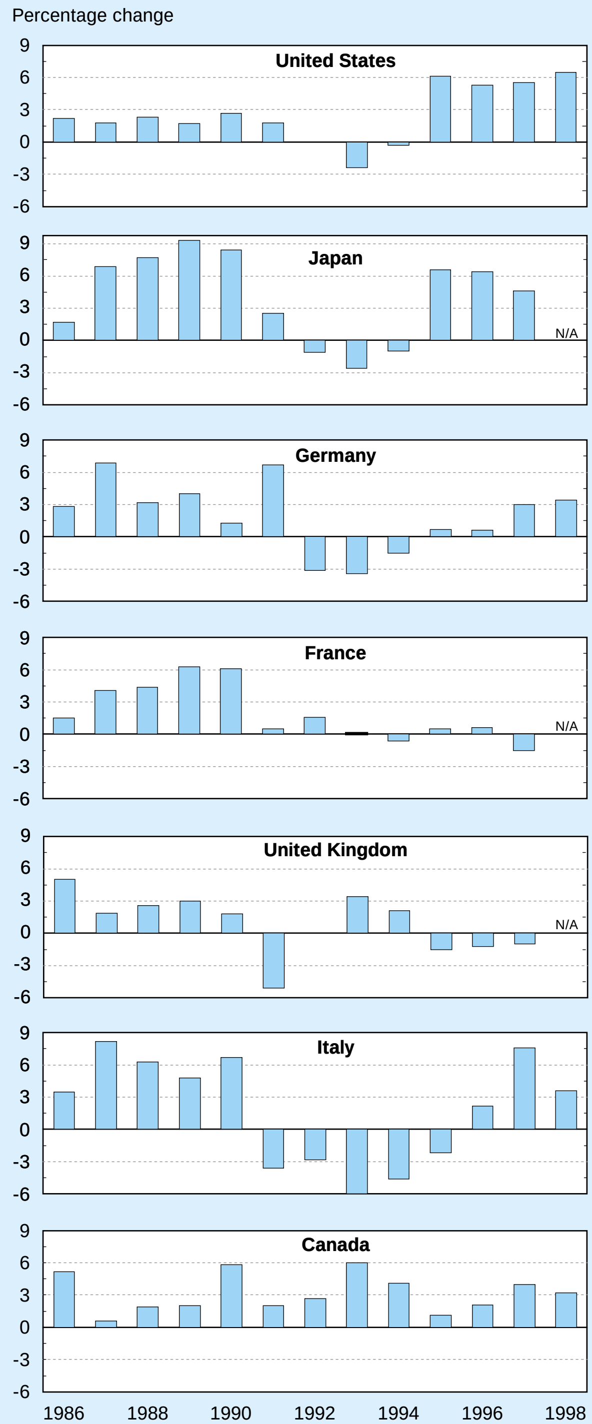
Figure 2-28.
Rates of change in total inflation-adjusted R&D spending



N/A = not available

NOTES: The inflation-adjusted R&D expenditures reflected in this graph are denominated in foreign currencies deflated by the countries' own GDP price deflators, and therefore are not distorted by exchange rate conversions.

See appendix table 2-63.

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experienced substantially reduced R&D spending in the early 1990s (OECD 1999d). For most of these countries, economic recessions and general budgetary constraints slowed industrial and government sources of R&D support. More recently, R&D spending has rebounded in several of the G-7 countries (though not in France or the United Kingdom, according to the latest available statistics), as has R&D spending in the United States. Yet since annual R&D growth generally has been stronger in the U.S. than elsewhere (see figure 2-28), the difference between the U.S. and the combined other G-7 countries' R&D spending has continued to narrow.

Concurrent with the relative increase in the U.S. share of the G-7 countries' R&D performance has been a reduction in the U.S. R&D share of all OECD countries' R&D spending. In 1986 the United States accounted for 48 percent of the R&D reported by OECD countries; by 1997 the U.S share had dropped to less than 43 percent of the OECD R&D total. Part of this share reduction (perhaps up to 2 percentage points) resulted from the addition of several countries to OECD mem-

Purchasing Power Parities: Preferred Exchange Rates for Converting International R&D Data

Comparisons of international statistics on R&D are hampered by the fact that each country's R&D expenditures are denominated, obviously, in its home currency. Two approaches are commonly used to normalize the data and facilitate aggregate R&D comparisons. The first method is to divide R&D by GDP, which results in indicators of relative effort according to total economic activity and circumvents the problem of currency conversion. The second method is to convert all foreign-denominated expenditures to a single currency, which results in indicators of absolute effort. The first method is a straightforward calculation, but it permits only gross national comparisons. The second method permits absolute-level comparisons and analyses of countries' sector- and field-specific R&D investments, but it entails choosing an appropriate currency conversion series.

Because (for all practical purposes) there are no widely accepted R&D-specific exchange rates, the choice is between market exchange rates (MERs) (available from IMF 1998) and purchasing power parities rates (PPPs) (available from OECD 1999d). These rates are the only series consistently compiled and available for a large number of countries over an extended period of time.

At their best, MERs represent the relative value of currencies for goods and services that are traded across borders; that is, MERs measure a currency's relative international buying power. Sizeable portions of most countries' economies do not engage in international activity, however, and major fluctuations in MERs greatly reduce their statistical utility. MERs also are vulnerable to a number of distortions—currency speculation, political events such as wars or boycotts, and official currency intervention—that have little or nothing to do with changes in the relative prices of internationally traded goods.

For these reasons, an alternative currency conversion series—PPPs—has been developed (Ward 1985). PPPs take into account the cost differences across countries of buying a similar basket of goods and services in numerous expenditure categories, including nontradables. The PPP basket is therefore representative of total GDP across countries. When the PPP formula is applied to current R&D expenditures of other major performers—such as Japan and Germany—the result is a substantially lower estimate of total research spending than that given by MERs. (See figure 2-29.) For example, Japan's R&D in 1996 totaled $85 billion based on PPPs and $130 billion based on MERs; German R&D was $40 billion and $54 billion, respectively. (By comparison, U.S. R&D was $197 billion in 1996.)

PPPs are the preferred international standard for calculating cross-country R&D comparisons wherever possible and are used in all official OECD R&D tabulations. Unfortunately, they are not available for all countries and currencies. They are available for all OECD countries, however, and are therefore used in this report. Although there is considerable difference in what is included in GDP-based PPP items and R&D expenditure items, the major components of R&D costs—fixed assets and the wages of scientists, engineers, and support personnel—are more suitable to a domestic converter than to one based on foreign trade flows. Exchange rate movements bear little relationship to changes in the cost of domestically performed R&D. (See figure 2-29.) When annual changes in Japan's and Germany's R&D expenditures are converted to U.S. dollars with PPPs, they move in tandem with such funding denominated in their home currencies. Changes in dollar-denominated R&D expenditures converted with MERs exhibit wild fluctuations that are unrelated to the R&D purchasing power of those investments. MER calculations indicate that, between 1986 and 1996, German and Japanese R&D expenditures each increased in three separate years by 20 percent or more. In reality, nominal R&D growth never exceeded 12 percent in either country during this period. PPP conversions generally mirror the R&D changes denominated in these countries' home currencies.

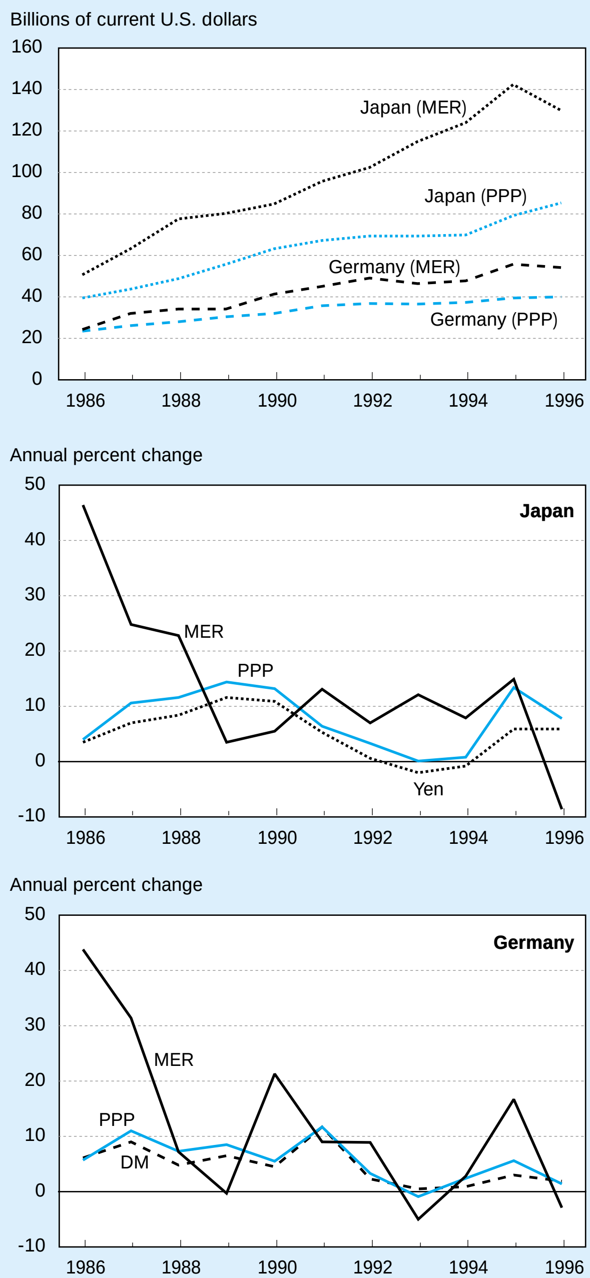
bership (thereby increasing the OECD R&D totals); worldwide growth in R&D activities, however, was a greater contributing factor to the loss of R&D share experienced by the United States. If actual "world" R&D totals were available (rather than for the OECD countries only), the decline in the U.S. share would likely be more pronounced.

Distribution of Nondefense R&D Expenditures

The policy focus of many governments on economic competitiveness and commercialization of research results has shifted attention from nations' total R&D activities to nondefense R&D expenditures as indicators of scientific and technological strength.[40] Indeed, conclusions about a country's relative standing may differ dramatically depending on whether total R&D expenditures are considered or defense-related expenditures are excluded from the totals. In absolute dollar terms, the U.S. international nondefense R&D position is still considerably more favorable than that of its foreign counterparts; the

[40]This is not to say that defense-related R&D does not benefit the commercial sector. Unquestionably, technological spillovers have occurred from defense to the civilian sector. Almost as certainly, however, the benefits are less than if these same resources had been allocated directly to commercial R&D activities. Moreover, considerable anecdotal evidence indicates that the direction of technological flow is now more commonly from commercial markets to defense applications rather than the reverse.

Figure 2-29.
Japanese and German R&D expenditures and annual changes in R&D estimates



NOTES: MER = market exchange rate; PPP = purchasing power parity; DM = deutsche mark

See appendix tables 2-1, 2-2 and 2-63.

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United States is not nearly as dominant, however, as when total R&D expenditures are compared. In 1996 (the latest year for which comparable international R&D data are available from most OECD countries), U.S. nondefense R&D was almost twice that of Japan's, but the non-U.S. G-7 countries' combined nondefense total was 17 percent more than nondefense R&D expenditures in the United States alone.

Between 1982 and 1990, growth in U.S. nondefense R&D spending was similar to nondefense R&D growth in other industrial countries (except Japan, where nondefense R&D expenditure growth was notably faster). As an equivalent percentage of the U.S. nondefense R&D total, comparable Japanese spending jumped from 45 percent in 1982 to 55 percent in 1990. (See appendix table 2-64.) During this period, Germany's annual spending equaled 26–29 percent of U.S. nondefense R&D spending. France's annual spending during this same period was equivalent to 17–18 percent of the U.S. total, and the United Kingdom's annual spending fluctuated narrowly between 14 and 16 percent of the U.S. total.

Since 1990, the worldwide slowing in R&D spending and the subsequent industrial rebound in the U.S. has narrowed the gap between U.S. nondefense R&D spending and that in the other G-7 countries. In 1996, the combined nondefense R&D spending in the six non-U.S. G-7 countries is estimated at $173 billion (in constant PPP dollars), compared with $148 billion (constant dollars) in the United States. Japanese and German nondefense spending relative to U.S. spending declined to 52 and 24 percent, respectively.

Trends in Total R&D/GDP Ratios

One of the most widely used indicators of a country's commitment to growth in scientific knowledge and technology development is the ratio of R&D spending to GDP. (See figure 2-30.) For most of the G-8 countries (that is, the G-7 countries plus the Russian Federation), the latest R&D/GDP ratio is no higher now than it was at the start of the 1990s, which ushered in a period of slow growth or decline in their overall R&D efforts. The ways in which different countries have reached their current ratios vary considerably, however.[41] The United States and Japan each reached local peaks—at 2.7 and 2.8 percent, respectively—in 1990–91. As a result of reduced or level spending by industry and government in both countries, the R&D/GDP ratios declined several tenths of a percentage point, before rising again to 2.7 and 2.9 percent. Growth in industrial R&D accounted for most of the recovery in each of these countries. Electrical equipment, telecommunications, and computer services companies have accounted for some of the strongest R&D growth since 1995 in the United States. In Japan, spending increases were highest in the electronics, ma-

[41]A country's R&D spending and therefore its R&D/GDP ratio is a function of several factors in addition to its commitment to supporting the R&D enterprise. Especially because the majority of R&D is performed by industry in each of these countries, the structure of industrial activity can be a major determinant of the level and change in a country's R&D/GDP ratio. Variations in such spending can result from differences in absolute output, industrial structure, and R&D intensity. Countries with the same size economy could have vastly different R&D/GDP ratios depending on the share of industrial output in the economy, whether the industries that account for the industrial output are traditional sites of R&D activity (for example, food processing firms generally do less R&D than do pharmaceutical companies), and whether individual firms in the same industries devote substantial resources to R&D or emphasize other activities (that is, firm-specific intensities). For example, economies with high concentrations in manufacturing (which has traditionally been more R&D intensive than nonmanufacturing or agricultural economies) have different patterns of R&D spending. See text table 2-13 for the distribution of industrial R&D performance in the G-7 countries and Sweden (which has the highest R&D/GDP ratio in the world).

Text table 2–13.
Share of industrial R&D by industry sector for selected countries

	Percent of industrial R&D performance total							
	Canada 1997	Germany 1995	France 1996	Italy 1997	Japan 1996	United Kingdom 1997	Sweden 1995	United States 1996
Total manufacturing	60.9	94.6	87.7	83.6	94.5	80.4	87.5	80.5
Food, beverages & tobacco	1.1	0.8	1.8	1.2	2.5	1.9	1.2	1.1
Textiles, fur & leather	0.6	0.6	0.6	0.4	0.8	0.3	0.2	0.3
Wood, paper, printing, publishing	1.8	0.5	0.4	0.2	1.2	0.5	3.0	2.0
Coke, ref. petrol. prod. & nucl. fuel	0.9	0.2	1.3	0.6	0.6	3.7	0.3	1.1
Chemicals & chemical products	8.5	17.9	18.6	13.9	15.8	29.6	16.3	13.0
Chemicals (less Pharmaceuticals)	2.1	13.3	6.3	5.9	9.2	7.1	2.0	6.3
Pharmaceuticals	6.3	4.6	12.3	8.0	6.6	22.5	14.3	6.8
Rubber & plastic products	0.4	1.5	2.5	1.9	2.6	0.6	1.0	1.0
Non-metallic mineral products	0.1	1.0	1.2	0.3	2.1	0.5	0.5	0.3
Basic metals	1.8	1.0	1.7	1.0	3.5	0.6	1.2	0.5
Fabricated metal products	0.9	1.4	1.2	2.7	1.5	0.9	1.1	1.1
Machinery eq., instruments & trans. equip.	44.1	69.0	57.7	61.3	63.1	41.5	62.5	59.6
Machinery, n.e.c.	1.9	11.3	4.6	5.3	8.7	5.8	10.8	4.2
Office, account. & computing machinery	4.1	3.9	2.6	3.7	9.9	1.1	1.4	8.8
Electrical machinery	0.9	7.2	3.4	4.8	10.9	4.4	1.6	2.3
Electro. equip.(radio, TV & comm.)	23.8	10.0	11.5	19.4	16.1	6.9	19.9	13.2
Instruments, watches & clocks	1.2	6.0	9.5	1.8	3.6	3.5	6.9	8.4
Motor vehicles	1.8	21.2	11.9	14.7	12.8	10.1	16.4	11.1
Other transport equipment	10.3	9.4	14.3	11.6	1.1	9.8	5.5	11.6
Aerospace	10.3	8.1	13.7	9.7	0.7	9.3	5.1	11.2
Ships, other transport nec.	0.1	1.2	0.6	2.0	0.3	0.4	0.5	0.3
Furniture, other manufacturing nec.	0.7	0.6	0.6	0.1	0.8	0.3	0.2	NA
Electricity, gas & water	2.6	0.4	3.1	3.0	1.1	1.4	0.9	0.2
Construction	0.2	0.3	0.7	0.3	2.2	0.1	0.5	0.2
Total services	33.5	3.5	6.9	13.1	4.2	17.5	10.0	19.5
Wholesale, retail trade, motor veh. repair etc.	6.4	0.1	NA	0.2	NA	0.1	NA	4.4
Hotels & restaurants	NA	NA	NA	0.0	NA	NA	NA	0.2
Transport & storage	0.2	0.2	2.9	0.2	0.1	0.1	0.2	0.2
Communications	2.1	NA	NA	4.1	2.4	5.2	2.5	2.8
Financ. intermediation (inc. insur.)	5.5	0.1	NA	0.0	NA	NA	NA	0.9
Real estate, renting & bus. activities	19.3	2.5	3.9	8.4	1.8	12.0	7.1	NA
Computer & related activities	6.8	0.4	2.3	1.1	1.8	7.4	1.5	5.1
Research & development	9.6	0.7	NA	5.9	NA	3.5	5.0	3.8
Other business activities nec.	2.9	1.4	1.6	1.4	NA	1.2	0.6	NA
Comm., soc. & pers. serv. activ.,etc.	NA	0.1	NA	0.2	NA	0.1	0.2	NA

NA= Not available separately

NOTE: The underlying OECD detailed data do not sum to 100 percent.

SOURCE: Organisation for Economic Co-operation and Development (OECD), ANBERD Database (DSTI/EAS Division), 1999.

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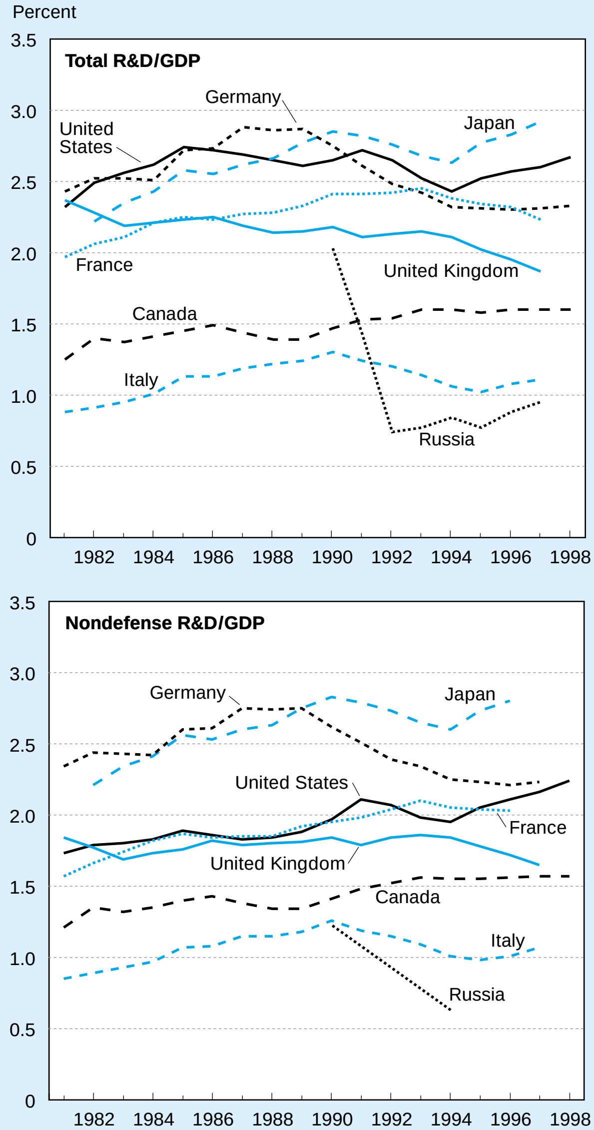
chinery, and automotive sectors and appear to be associated mainly with a wave of new digital technologies (IRI 1999). In addition, Japan's national government also has contributed to some of the renewed vigor in Japan's R&D spending. (See NSF 1997 for a summary of the Japanese government's intent to double Japan's R&D budget.)

By comparison—and with the notable exception of Canada, for which the R&D/GDP ratio has remained relatively level since the early 1990s—the other G-8 countries each report lower R&D shares now than at the beginning of the decade. The smallest share reductions occurred in Italy, the United Kingdom, and France (declining about two-tenths of a percentage point in each country, to current ratios of 1.0, 1.9, and 2.3 percent, respectively). In Germany, the R&D/GDP ratio fell from 2.9 percent at the end of the 1980s, before reunification, to its current level of 2.4 percent. The end of the Cold War and collapse of the Soviet Union had a drastic effect on Russia's R&D enterprise. R&D spending in Russia was estimated at 1.4 percent of GDP in 1991; that figure plummeted to 0.7 percent in 1992. Moreover, the severity of this R&D decline is masked somewhat in that while the R&D share was falling, it also was a declining share of a declining GDP. By 1997, R&D spending in Russia had inched back to about 1.0 percent of GDP.

Figure 2-30.
R&D as a percentage of GDP, G-8 countries



See appendix tables 2-63 and 2-64.

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Text table 2–14.
R&D as a percentage of gross domestic product

Sweden	3.85	Russian Federation	0.95
Japan	2.92	Venezuela	0.89
South Korea	2.89	Spain	0.86
Finland	2.78	Brazil (1996)	0.76
Switzerland (1996)	2.74	Poland	0.76
United States	2.60	Hungary	0.73
Germany	2.31	Cuba	0.70
Israel	2.30	South Africa	0.69
France	2.23	China	0.65
Netherlands (1996)	2.09	Portugal	0.65
Denmark	2.03	Chile	0.64
China (Taipei)	1.92	Indonesia (1995)	0.50
United Kingdom	1.87	Greece (1993)	0.48
Australia (1996)	1.68	Turkey (1996)	0.45
Norway	1.68	Uruguay	0.42
Canada	1.60	Colombia	0.41
Belguim (1995)	1.58	Argentina	0.38
Iceland	1.56	Panama	0.38
Austria	1.52	Malaysia (1994)	0.34
Singapore	1.47	Bolivia (1996)	0.33
Ireland	1.43	Mexico	0.42
Czech Republic	1.19	The Philippines (1992)	0.21
Slovak Republic	1.18	Thailand (1996)	0.12
Costa Rica (1996)	1.13	Hong Kong (1996)	0.10
New Zealand	1.10	Ecuador (1996)	0.08
Italy	1.08		

NOTES: Unless noted otherwise, data are for 1997.
Data for Israeli and China (Taipei) include nondefense R&D only.

Total OECD	2.17
North America	2.36
European Union	1.84

SOURCES: Organisation for Economic Co-operation and Development (OECD 1999), Centre for Science Research and Statistics (CSRS 1999), Red Iberomericana de Indicatores de Ciencia y Tecnologia (RICYT 1998), Israel Central Bureau of Statistics (1998), South Africa FRD (1998), National Science Council (1998), and Pacific Economic Cooperation Council (PECC 1997).

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Overall, the United States ranked sixth among OECD countries in terms of reported R&D/GDP ratios for the 1995–97 period. (See text table 2-14.) Sweden leads all countries with 3.9 percent of its GDP devoted to R&D—followed by Japan and South Korea (2.9 percent); Finland (2.8 percent); and Switzerland (2.7 percent). In general, southern and eastern European countries tend to have R&D/GDP ratios below 1.5 percent, whereas northern European nations and non-European OECD countries report R&D spending shares above 1.5 percent.

Nondefense R&D/GDP Ratios

Compared with total R&D/GDP ratios, the relative position of the United States is slightly less favorable if only nondefense R&D is considered. Japan's nondefense R&D/GDP ratio (2.8 percent) exceeded that of the United States (2.1 percent) in 1996, as it has for years. (See figure 2-30 and appendix table 2-64.) The nondefense R&D ratio of Germany (2.2 percent) slightly exceeded that of the United States (again, in contrast to total R&D). The 1996 nondefense ratio for France (2.0 percent) was slightly below the U.S. ratio; those for the United Kingdom (1.7 percent), Canada (1.6 percent), and Italy (1.0 percent) were much lower. The most recent nondefense R&D/GDP ratio for Russia was a 0.6 percent share in 1994.

Consistent with overall R&D funding trends, however, the U.S. nondefense R&D/GDP ratio has been improving relative to each of the G-8 countries since 1994, when ratios reported for Japan and Germany exceeded that for the United States. France also reported devoting more of its economic output to nondefense R&D activities than did the United States, and the relative ratio of U.K. nondefense R&D spending to GDP was about equal to that in the United States. Led by industry's investments in research and predominantly development spending, the U.S. nondefense R&D/GDP ratio now matches or exceeds each of the world's other major R&D performing countries (except Japan).

Emerging Countries' R&D Investments

Outside the European region, R&D spending has intensified considerably since the early 1990s. Several Asian countries—most notably South Korea and China—have been particularly aggressive in expanding their support for R&D and S&T-based development.[42] In Latin America and the Pacific region, other non-OECD countries also have attempted to substantially increase R&D investments during the past several years (APEC/PECC 1997; RICYT 1998).[43]

Even with recent gains, however, most non-European (non-OECD) countries invest a smaller share of their economic output on R&D than do OECD members (with the exception of Israel—whose reported 2.3 percent nondefense R&D/GDP ratio ranks eighth in the world). With the apparent exception of Costa Rica, all Latin American countries for which such data are available report R&D/GDP ratios below 1 percent. (See text table 2-14.) This distribution is consistent with broader indicators of economic growth and wealth. However, many of these countries also report additional S&T-related expenditures on human resources training and S&T infrastructure development that are not captured in R&D and R&D/GDP data (RICYT 1998).

R&D in the Russian Federation in Transition

As recently as 1990, R&D accounted for about 2 percent of the Soviet Union's GDP, with about 40 percent of that amount expended on defense-related activities (Gohkberg, Peck, and Gacs 1997).[44] Indeed, the most advanced aspects of Soviet R&D efforts were undertaken in state-owned enterprises devoted to national security; much of the remaining R&D was performed in other large public industrial institutions in applied research fields that overlapped defense concerns. Most of the basic research was and continues to be in the physical sciences and engineering fields.

[42]Also see NSF (1993) and NSF (1995) for a discussion of S&T trends in several Asian countries. See NSF (1996) for information on growth in S&T activities in Europe.

[43]In addition to expanding their R&D investments, an increasing number of countries worldwide have expended considerable efforts to collect and publish science and technology (including R&D) statistics that are internationally comparable. One such effort is coordinated by the Iberoamerican Network of Science and Technology Indicators (RICYT). The Network aims to design, collect, and publish S&T indicators, as well as to train professionals specialized in these subjects (Albornoz and Poluch 1999). Together with assistance from the Organization of American States (OAS) and the Iberoamerican Program on Science and Technology for Development, RICYT has published several S&T indicator reports (available at <<http://www.unq.edu.ar/ricyt>>). The Network has the participation of all countries in the Americas, as well as that of Spain and Portugal. Similar efforts have been underway for Pacific-based economies that are members of the Asia-Pacific Economic Cooperation (APEC) and the Pacific Economic Cooperation Council (PECC).

[44]R&D data for the Russian Federation are taken from Centre for Science Research and Statistics surveys designed to collect such statistics in accordance with OECD international standards.

The introduction of a market economy to Russia brought about drastic economic restructuring, including a sharp decline in the dominance of state-owned enterprises and a 25 percent shrinkage in real GDP in just two years (IMF 1998). These trends, in turn, brought about major R&D downsizing; real R&D expenditures in 1992 collapsed to only 30 percent of the inflation-adjusted levels reported for 1990 (CSRS 1999). That is, real spending on R&D fell 70 percent with a resultant R&D/GDP ratio of about 0.7 percent. (See text table 2-15.) Reflecting the lack of core budgets, between 1990 and 1992 entire research institutes closed—including many well-equipped laboratories of the former military-industrial complex—and an estimated 19 percent of all researchers left their government R&D laboratories for the commercial sector or retirement or for other reasons, including emigration.[45]

Between 1992 and 1995, Russian R&D spending continued to deteriorate, though at a slower pace, falling 25 percent in real terms (for a total decrease of 78 percent since the start of the decade) (CSRS 1999; OECD 1998b). The rate at which researchers left their labs accelerated, however; the number of researchers at government facilities declined 39 percent during the 1992–95 period, reflecting the effect of low and unpaid salaries, declining budgets for capital and research equipment, and generally inhospitable working conditions.

In terms of R&D spending, the situation in Russia has improved slightly since 1995. Fueled by government and industrial spending, growth in R&D exceeded inflation in 1996 and 1997. Similarly, funds from foreign sources (including funding from

[45]Other former communist countries have experienced similar patterns of initial decline and restructuring in their R&D enterprise. In the transition toward market economies, however, the pattern has varied considerably among countries, reflecting the diversity of their economic and social histories and experiences (e.g., business orientation, technological openness, and role of higher education). For a review of country-specific differences and recent developments in Hungary, Poland, the Czech Republic, Slovakia, Romania, and Russia, see Radosevic and Auriol (1999).

Text table 2–15.
Indicators of R&D in the Russian Federation

	R&D (Billions of 1989 rubles)	R&D/GDP	R&D Personnel: Total*	Researchers (thousands)	Technicians
1990	10.898	2.03	1,943	993	235
1991	7.290	1.43	1,678	879	201
1992	3.225	0.74	1,533	804	181
1993	3.055	0.77	1,315	645	134
1994	2.930	0.84	1,106	525	116
1995	2.446	0.77	1,061	519	101
1996	2.603	0.88	991	485	88
1997	2.797	0.95	935	455	80

* Includes science and engineering researchers, technicians, and other supporting staff.

SOURCE: Center for Science Research and Statistics (CSRS) *Russian Science and Technology at a Glance: 1998* (Moscow: CSRS, 1999)

Science & Engineering Indicators – 2000 the European Union and the U.S. Civilian Research Foundation, among others) tripled between 1995 and 1997 and now account for 7 percent of domestic R&D spending in Russia (CSRS 1999). In spite of these recent gains, real R&D spending remains 13 percent below the levels reported for 1992 and 75 percent below the estimated levels at the beginning of the decade. Furthermore, the outflow of researchers from such activities is still an important concern, as is the belief that the younger generation is not choosing science and engineering careers to the same extent as previously. Between 1995 and 1997, an estimated 65,000 scientists and engineers left their R&D work, resulting in a researcher workforce level (455,000) that was less than half of the estimated 1990 level (993,000).

International R&D by Performer, Source, and Character of Work

Performing Sectors

The industrial sector dominates R&D performance in each of the G-7 countries. (See figure 2-31.) Industry performance shares for the 1996–98 period ranged from a little more than 70 percent in the United States and Japan to less than 54 percent in Italy. Industry's share was between 60 and 70 percent in Germany, France, the United Kingdom, and Canada.[46] Most of the industrial R&D performance in these countries was funded by industry. Government's share of funding for industry R&D performance ranged from as little as 1 percent in Japan to 15 percent in the United States. (See appendix table 2-65.) By comparison, industry performance in Russia accounted for a 66 percent share of the total. However, government was the source of half of these funds (as contrasted with government's 15 percent or smaller shares in the G-7 countries), and industry itself funded just 40 percent of the Russian industrial R&D performance total.[47]

In most of these countries, the academic sector was the next-largest R&D performer (at about 12 to 25 percent of the performance total in each country).[48] Academia often is the primary location of research (as opposed to R&D) activities, however. Government was the second-largest R&D performing sector in France (which included spending in some sizeable government laboratories) and the U.S. (which includes FFRDCs), as it was in Russia (accounting for 28 percent of that nation's R&D effort). By comparison, government's R&D performance share was smallest in Japan, at about 10 percent of the country's total.

Sources of Funds

Industry R&D Funding

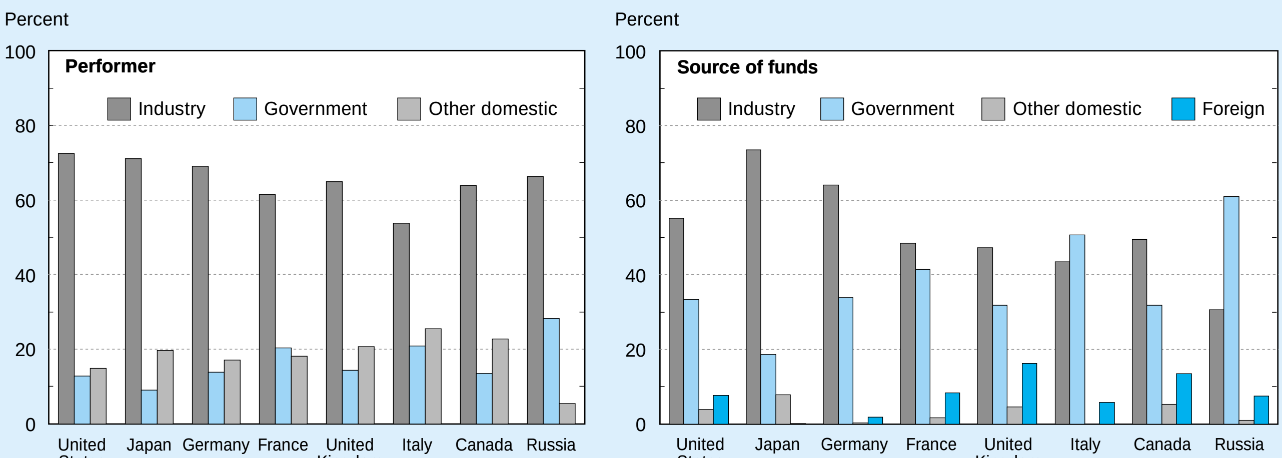
Consistent with the fact that the industrial sector performs most of these countries' R&D activities, it provides the great-

[46]See text table 2-13 for the distribution of industrial R&D performance in the G-7 countries and Sweden. For detailed data on industry-specific R&D activities in other OECD countries, see OECD 1999b.

[47]Although the economic structure of the Russian system still differs considerably from that of the G-7 countries, these data were compiled and adjusted by the Russian R&D statistics organization, CSRS (1999), according to OECD sector categories to allow international comparison.

[48]The national totals for Europe, Canada, and Japan include the research component of general university funds (GUF) block grants—not to be confused with basic research—provided by all levels of government to the academic sector. Therefore, at least conceptually, the totals include academia's separately budgeted research and research undertaken as part of university departmental R&D activities. In the United States, the Federal Government generally does not provide research support through a GUF equivalent, preferring instead to support specific, separately budgeted R&D projects. On the other hand, a fair amount of state government funding probably does support departmental research at public universities in the United States. Data on departmental research, considered an integral part of instructional programs, generally are not maintained by universities. U.S. totals may thus be underestimated relative to the R&D effort reported for other countries.

Figure 2-31.
R&D expenditures, by country, performer, and source: 1996–98



NOTE: Foreign performers are included in the "industry" and "other domestic" performing sectors.

See appendix table 2-65.

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